Summer 2021

JME 4110: Vibratory Parts Feeder

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Joint Engineering Program

University of Missouri–St. Louis ▪ Washington University in St. Louis

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The purpose of a vibratory parts feeder is to move product from one location to another while sorting or reorienting the objects. The prototype we built utilizes a concrete vibration motor (modified) that is attached to a base frame assembly. That base frame is then attached to a sorting through via springs to allow for vibratory oscillations from the motor.

JME 4110
Mechanical Engineering
Design Project

Vibratory Parts Feeder

Noah Herrin
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Adin Stambolic

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1 INTRODUCTION

1.1 VALUE PROPOSITION / PROJECT SUGGESTION

The parts we envision in project 7 will need to be transported between the mixer, producer, and modification station. Design inexpensive, modular, tunable vibratory feeders to move the parts from one place to another. Ideally, the feeder can be programmed to change shape and size during a run as the parts are modified.

1.2 LIST OF TEAM MEMBERS

Noah Herrin - Project Manager

Patrick Vastola - Documentation, CAD, and Codes & Standards

Adin Stambolic - Design Calculation and Scheduler

2 BACKGROUND INFORMATION STUDY

2.1 DESIGN BRIEF

Design an inexpensive, modular and tunable vibratory feeder to move different size particles from one place to another. The feeder can change according to the shape and size of the particles while in use.

2.2 BACKGROUND SUMMARY

1. https://www.mpelettronica.com/en/how-do-electromagnetic-vibratory-feeder-works/

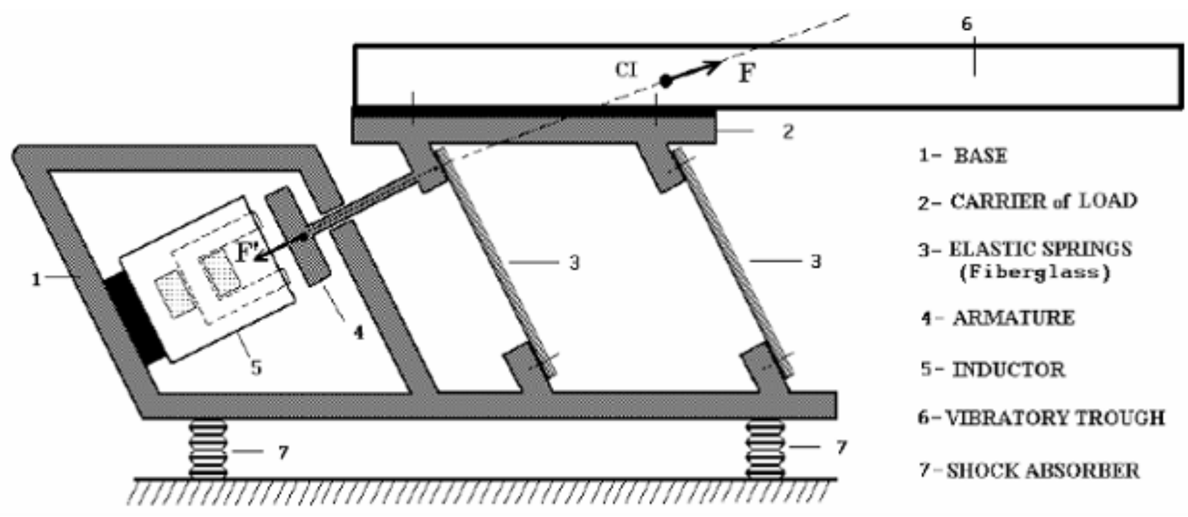


Figure 1 - Basic linear vibrating feeder

This link gives a brief explanation how a vibrating feeder works. A linear vibrator works by inducing a current in a coil at high frequency, pulling and pushing a nearby magnet which creates the physical vibration.

2. https://www.goughengineering.com/en/blog/vibratory-feeder-working-principle

Figure 2 - Vibratory feeder and base

This link gives a more in-depth explanation of a linear vibratory parts feeder.

3.https://patents.google.com/patent/US7413073B2/en?q=linear+vibrating+feeder&oq=linear+vibrating+feeder

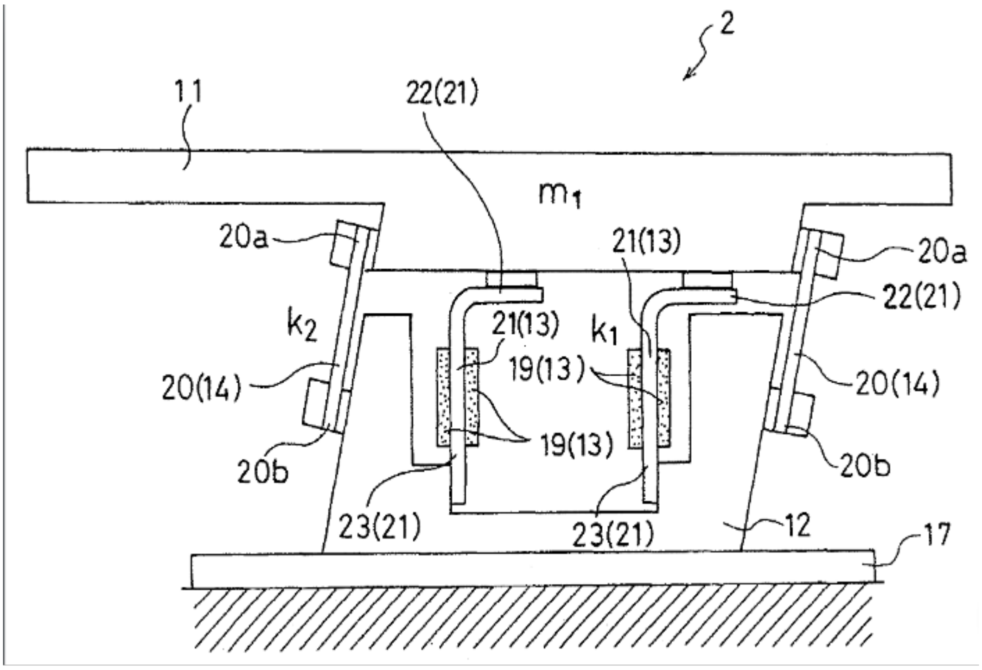


Figure 3 - Patent drawing for a parts feeder

Above is a figure from a patent for a "piezo-driven parts feeder". It consists of a moving table mounted on top of a stationary table via an electromagnetic vibrator connected to two elastic parts. There is a magnet fixed to the moving table. A current is induced at a high frequency causing the magnet to move the table back and forth.

3 CONCEPT DESIGN AND SPECIFICATION

3.1 USER NEEDS AND METRICS

Scale; 1 (least important) to 5 (most important)

Table 1 - User Design Needs

Project/Product Name: Vibratory Parts Feeder			
Customer: Mark Jakiela Address: Washington University Willing to do a follow up? Yes Type of user: ?		Interviewers: Patrick Vastola, Adin Stambolic, Noah Herrin Date: June 28, 2021 Currently uses: ?	
Question	**Customer Statement**	**Interpreted Need**	**Importance**
Type of feeder?	Linear track	Transportation from one place to another	5
Particles per minute?	1000 ppm	Speed	2
General size?	Fits on a desk	Size	2
Sort by size?	Yes	Sorting	4
What are your likes of a vibratory feeder?	Tunable, durable	Variable speed, Durability	3 3
What are the particles being deposited into?	bucket	Transportation	5
Do they need to be oriented a certain way?	Sorting	Sorting	4
What kind of shapes will the particles make? Symmetrical? Rolling?	Convex hull No angles	Sorting	4
How will the particles enter the feeder?	Hopper/funnel	Transportation	5

3.1.1 Record of the user needs interview

See table above.

3.1.2 List of identified metrics

See table above.

3.1.3 Table/list of quantified needs equations

See table above.

3.2 CONCEPT DRAWINGS

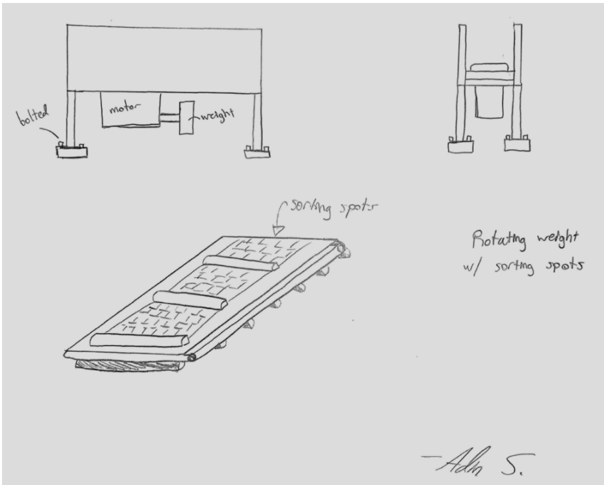


Figure 4 - Concept Drawing 1

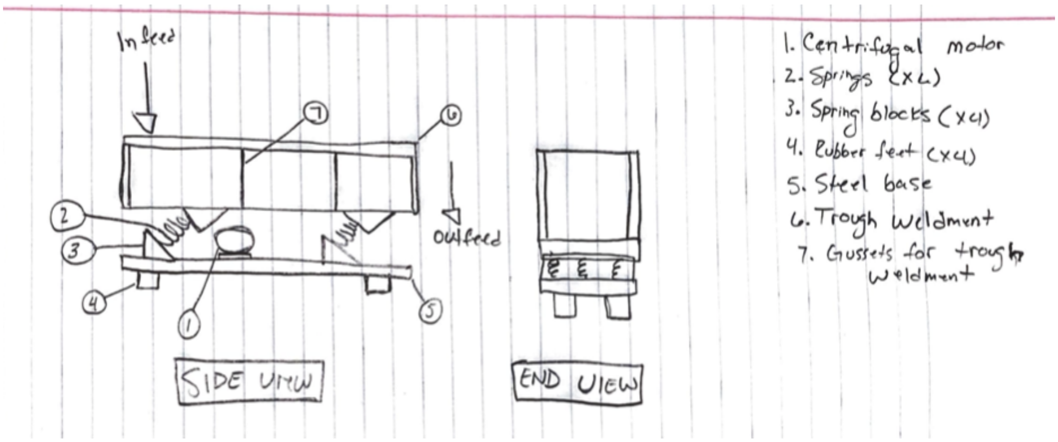


Figure 5 - Concept Drawing 2

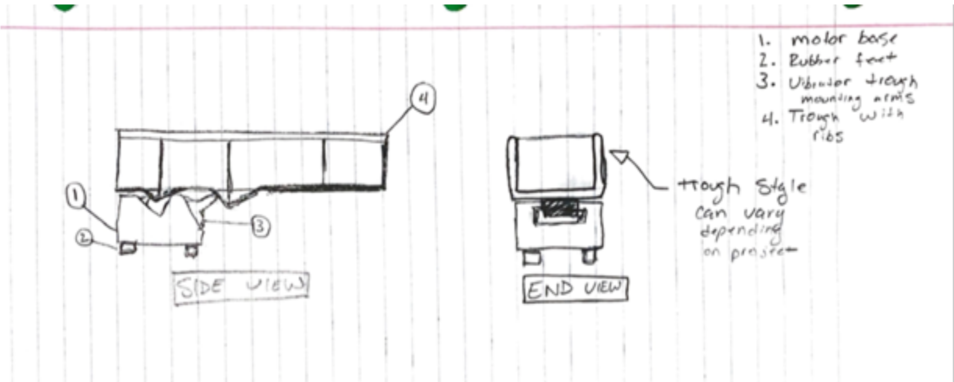


Figure 6 - Concept Drawing 3

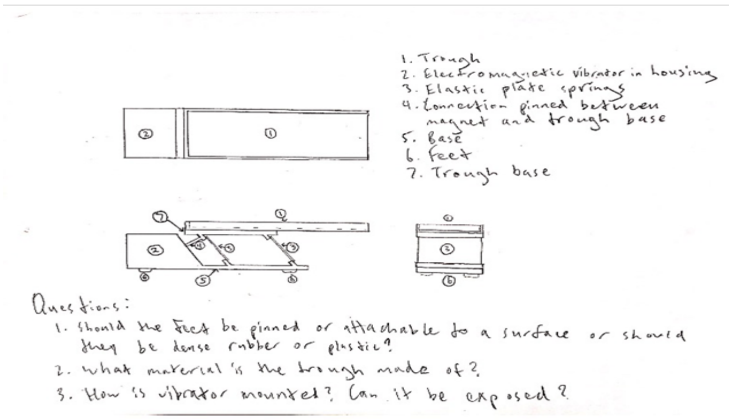


Figure 7 - Concept Drawing 4

3.3 A CONCEPT SELECTION PROCESS.

3.3.1 Concept scoring (not screening)

Table 2 - Concept Scoring

		Concept Scoring			
Criteria	**Rating (1 - 10)**	**Concept 1**	**Concept 2**	**Concept 3**	**Concept 4**
Type of Feeder - Linear	10	10	10	10	10
Adjustability - Sorts Different Sizes of Product	10	8	9	8	9
Build to Sort Product Shape - Tetrahedra	9	8	9	8	9
Speed of Sorting - 1000 ppm	8	6	8	7	9
Ability to Handle Product Material - Porcelain	7	10	10	10	10
Size of Feeder - Fits on Desk	6	9	8	10	9
Outfeed into Bucket	5	7	9	8	7
Parts Oriented to Specific Position	5	10	8	7	7
Infeed - from Hopper or Funnel	5	10	10	10	10
Cost of components	4	9	8	10	8
Ease of Welding	3	9	7	7	7
Ease of manufacture of individual components - spare parts	3	8	8	9	9
Type of Feeder - Bowl	1	0	0	0	0
Totals		646.00	665.00	651.00	667.00

3.3.2 Preliminary analysis of each concept's physical feasibility

Concept 1: For concept 1, there will be some difficulty around sourcing the components for the trough. The sorting tray at the bottom might become difficult to fabricate to the necessary specifications to work in the application of defect sorting.

Concept 2: This concept will have some physical limitations around cost. While this design is well built for longevity, its cost might outweigh the gain from its longevity. That being said, the cost of the materials is a necessary component for this project and may not be that big of a factor in the long run.

Concept 3: The main concept restraint for this design is the motor. While this design is commonly used in the field for small vibratory feeders, it would be difficult to service and replace. Whereas having an independent motor would greatly simplify the servicing or replacement without having to completely dismantle the whole unit.

Concept 4: This concept runs into the same issue as concept 3, the motor might cause complications further down the line if/when service and/or replacement is needed.

3.3.3 Final summary statement

3.4 PROPOSED PERFORMANCE MEASURES FOR THE DESIGN

Overall, the concept that we decided to go with was concept 2. While concept 4 did technically win the scoring, we are unable to source the motor that would be required and therefore cannot proceed on with it. However, concept 2 – being only two points away - was so close to concept 4 so it will not be a noticeable downgrade in any way. Because of this we had no reservations going with this concept instead.

3.5 REVISION OF SPECIFICATIONS AFTER CONCEPT SELECTION

Compared to the other concepts, its ability to transfer products effectively, efficiently, and in the manner that we want goes above the other options. It will have greater adjustability and will be able to move more products – hopefully hitting that 1000 parts per minute goal. Even though it will be compact in nature, it will be able to manage these large loads due to effective designs and proper movement of products. While it may slightly lack in its orientation goal of the product, the result of transferring the product to a bucket will be unmatched. Because of the design and certain features within that design, this feeder will save on some of the intricate welding that will be required, and more importantly, will save on some of the very large costs this project will entail. There are obviously some things we are worried about such as the orientation of parts and some certain components, however, we will be able to make adjustments as we go and figure out mechanisms to ensure our feeder delivers the parts in the most efficient way possible.

4 EMBODIMENT AND FABRICATION PLAN

4.1 EMBODIMENT/ASSEMBLY DRAWING

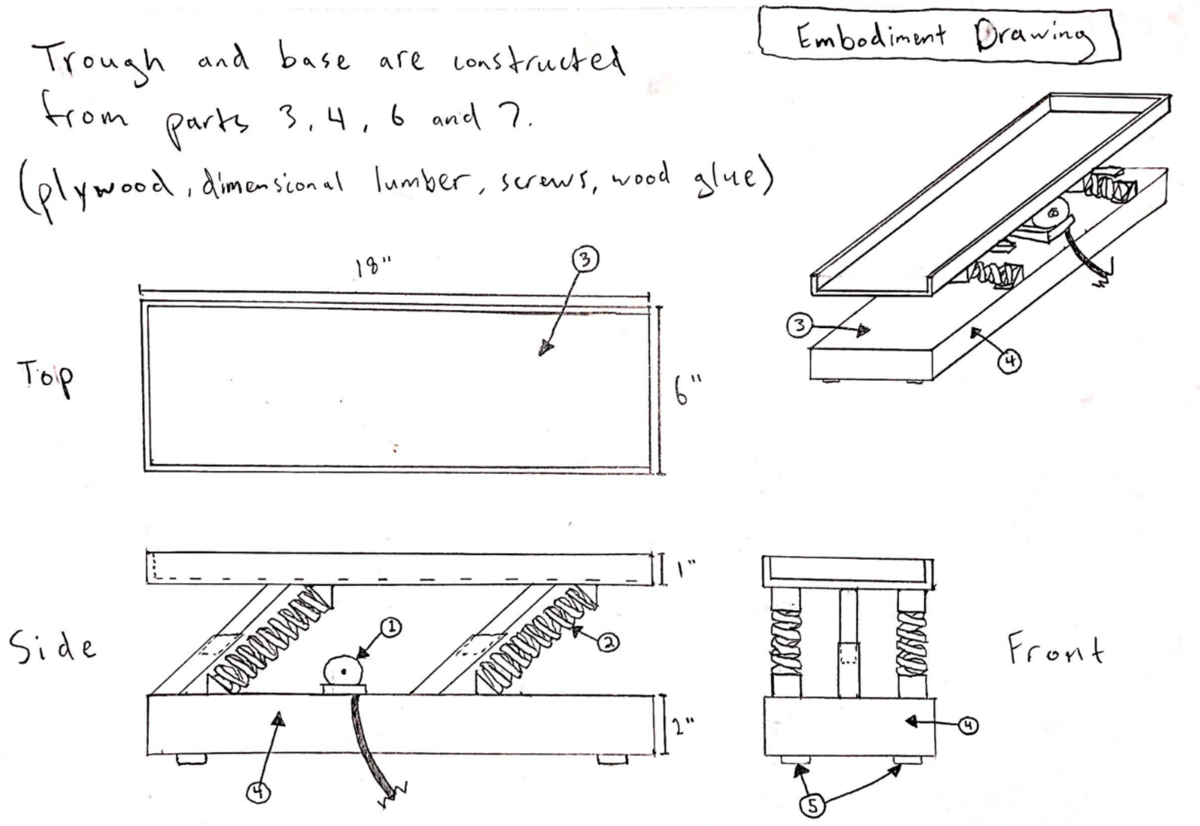


Figure 8 - Embodiment Drawing

4.2 PARTS LIST

Table 3 - Parts List

No.	Item Description	Vendor	Part Number	Unit	Unit Cost	Qty.	Material
1	US Stock 110V, 100W Motor	eBay	164178084183	Each	$69.99	1	
2	Tempered Steel Compression Spring	McMaster Carr	96485K135	Each	$11.75	4	Carbon steel
3	Plywood, 11/32" x 4' x 8' sheet	Home Depot	112590	Each	$33.33	1	Pine Wood
4	1in x 3in x 8ft. Kiln-Dried Whitewood	Home depot	418545	Each	$10.42	1	Whitewood
5	Vibration-Damping Mount w/ Unthreaded Hole	McMaster Carr	60525K25	Each	$4.08	4	PVC Plastic
6	#8 x 1-1/2 in. R4 Multi-Purpose Star Drive Flat Head Screw	Home Depot	96085	Box	$9.98	1	Steel
7	Titebond III 8 oz. Ultimate Wood Glue	Home Depot	202960636	Each	$5.97	1	Glue

4.3 DRAFT DETAIL DRAWINGS FOR EACH MANUFACTURED PART

See appendix C for detailed drawings.

4.4 DESCRIPTION OF THE DESIGN RATIONALE

During the embodiment design part of this project, we narrowed down some of the features and materials ideal for this build. I will discuss those rationales and engineering analysis below.

First, the subject of features was heavily discussed during the embodiment part of the project. We discussed the necessary components needed for this design and some other ones that would be beneficial but not critical. Of those, we decided on the base-frame design for the project. This design allowed for us to build the parts feeder to last and use less expensive materials, of which I will get into later. Additionally, this design was allotted for us to build it in the time frame allotted for this class.

Second, we chose the material of wood as the primary choice for our vibratory parts feeder. This material allowed us to be proficient in our delivery time and meet the deadline for this project. This was primarily driven by the lead-times/availability of materials and the commonality of tools available to build wooden projects. While a steel version might last a little longer, the materials would be difficult to get within the timeframe of this project.

Finally, the size of the vibratory parts feeder was decided upon via the approximate size of a desktop. Due to the size of the particles from Group 7's project, the size of the feeder would not need to be larger than that would fit on a desktop. The particles that Group 7 is creating will be ~6mm tetrahedral shaped.

5 ENGINEERING ANALYSIS

5.1 ENGINEERING ANALYSIS PROPOSAL

Analysis done before build

1. Identify major areas for errors – NH
    a. We will work through to identify areas with potential error within our chosen prototype. These errors can/will include:
        i. Ease of build
        ii. Cost of project
        iii. Longevity of product/machine
        iv. Tools available for prototype construction – will dictate what materials can be used
        v. Feasibility of design – too complex and we will not meet the deadline
2. Plan the build timeline for the project - PV
3. Identify long-lead items – AS

Analysis done after build

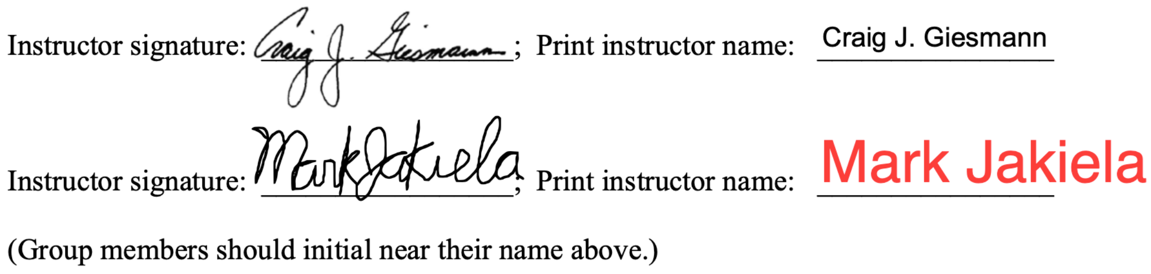
1. Structure analysis – NH, PV, AS
    a. Verify the base frame and trough are structurally sound
    b. Verify the frame to trough connection is secure and will retain longevity during operation.
2. Motor analysis - PV
    a. Analyze motor at different speeds to determine which one(s) work the best
3. Parts sorting analysis - AS
    a. Allow vibratory parts feeder to operate with tetrahedral parts to determine if the trough and sorting features work as intended.
4. Cost analysis - NH
    a. Verify project was done within budget.
    b. If not;
        i. Identify the sources of overspending in the project.

Noah Herrin - NH

Patrick Vastola - PS

Adin Stambolic - AS

5.1.1 Signed engineering analysis contract



Instructor signature: Craig J. Giesmann; Print instructor name: Craig J. Giesmann

Instructor signature: Mark Jakiela; Print instructor name: Mark Jakiela

(Group members should initial near their name above.)

Figure 9 - Signed Contract

5.2 ENGINEERING ANALYSIS RESULTS

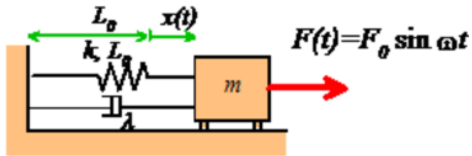
5.2.1 Motivation

The points of analysis were carefully chosen to fully look at the critical aspects of this project. The main motivation behind these analysis points is to be as efficient as possible in preparation for the prototype build and generate the best outcome after the prototype is complete. Before the prototype build, we will identify some major areas of possible error. These areas include; ease of build, cost projection, longevity of machine, tools available for construction, and feasibility of design. Identifying these areas will help us plan to avoid mishaps along the way.

After the prototype, we have a set list of areas to review. Those areas are as follows; structural analysis, motor analysis, parts sorting analysis, and cost analysis. Each of these points will be driven off the whole process of prototype development and execution. Retaining documents and notes from along the way will be vital to analyzing the prototype in retrospect.

5.2.2 Summary statement of analysis done

To summarize the engineering analysis done on this project, I have broken it down into several categories; vibrations, structural, and functional. For the vibration's analysis (figure 1), we used formulas below to calculate the oscillating motion of the trough/springs. Next, we used statics to calculate the structural rigidity of the build (figure 2). Lastly, we formulated guidelines that we wanted the function of the operation to follow.



Equation of Motion

$$\frac{1}{\omega_n^2}\frac{d^2x}{dt^2}+\frac{2\varsigma}{\omega_n}\frac{dx}{dt}+x=KF(t)$$

with

$$\omega_n=\sqrt{\frac{k}{m}}, \qquad \varsigma=\frac{\lambda}{2\sqrt{km}}, \qquad K=\frac{1}{k}$$

Steady State Solution:

$$x(t)=X_0\sin(\omega t+\phi)$$

$$X_0=\frac{KF_0}{\left\{\left(1-\omega^2/\omega_n^2\right)^2+\left(2\varsigma\omega/\omega_n\right)^2\right\}^{1/2}} \qquad \phi=\tan^{-1}\frac{-2\varsigma\omega/\omega_n}{1-\omega^2/\omega_n^2}$$

Figure 10 - Vibration Analysis of System

Static Analysis

Equation of equilibrium

$$\sum F_x=0 \qquad \sum F_y=0 \qquad \sum F_z=0$$

$$\sum M_x=0 \qquad \sum M_y=0 \qquad \sum M_z=0$$

If only x-y plane

$$\sum F_x=0 \qquad \sum F_y=0$$

$$\sum M=0$$

Figure 11 - Structural Analysis Equations

5.2.3 Methodology

In order to perform the described analysis above, we had to break it down into several sections. For the initial analysis, we used the risk predictor tool to project areas where our attention should be focused on. We outlined 10-15 risks that we believe could cause the project to be delayed. The top items generated from that tool were out of focus before going into the prototyping stage of the project. The main areas for concern evolved around the schedule and budget for the project. For the schedule, we used the Microsoft project timeline created for the project management and collaboration appendix 3 to project the deadlines of each task. This helped us identify some areas of error based on current standing and expected hours to complete. For the cost, we utilized the cost breakdown spreadsheet from project management and collaboration appendix 5 to track out materials needed and ordered to verify we stayed on budget.

The analysis done after the prototype build was more hands-on, whereas the “before” analysis was more hypothetical. We analyzed the frame members by loading the system down with the expected product weight and measuring any deflection in the frame or trough. Additionally, we visually inspected the trough supports and springs when the system was underweight to verify it was handling the load properly. Next, we analyzed the motor by means of dropping the product on the trough and calculating the speed at which it passed and fell off the end. The motor speed can be altered by how fast the product stream is moving. Furthermore, while the product is running through the trough, we inspected how the parts sorting feature was working by visually identifying the parts were being oriented properly. Lastly, a cost analysis will be done on the final cost of the build. This can be calculated by adding up the materials purchased.

5.2.4 Results

The results from our analysis above provided two things. First, the analysis of the physical components allowed for us to see how this would hold up. Second, the hypothetical analysis showed us the risks possible, the costs of delays, the overall projected cost of the project, and the added cost by delays.

Looking at the analysis of physical components, we can surmise that the structure will hold up to the expected forces exerted by the vibrations of the motor and springs. Also, reviewing the results from the hypnotical analysis we can determine that the project has a few sources of possible risk. These areas of risk can be combated with extra attention, so they do not fall behind.

5.2.5 Significance

How will the results influence our prototype? What materials did we use and what dimensions?

The results from our two types of analysis have meant that the design of our vibratory parts feeder will slightly change. Due to structural forces, the base of the feeder will need to increase in overall size. Additionally, the motor originally spec'd will need to be changed due to function of the trough and base. Furthermore, the trough design will change slightly depending on how well the sorting feature works. This is something we have theorized but not proven in a real-world test. This will be tested during the building of the project and improved upon as time progresses.

The material needed for this project was originally going to be steel. However, during the risk analysis we discovered that the metal shops we originally thought would be available to us were closed due to maintenance and/or upgrades. From this information, we then decided on wood as our primary material for the project. The base frame and trough would be made of wood and most of the other components would use steel, such as fasteners and springs.

Next, the dimensions of the build would need to change due to the material changes and structural forces needed. Originally, the design called for 18” base length by 6” base width. This area will increase by a factor of one and a half. That being said, the design will be as-built from this point on and we will make updates when we have built the actual project. Additionally, the height will inevitably change due to springs available to us within the spec we need.

6 RISK ASSESSMENT

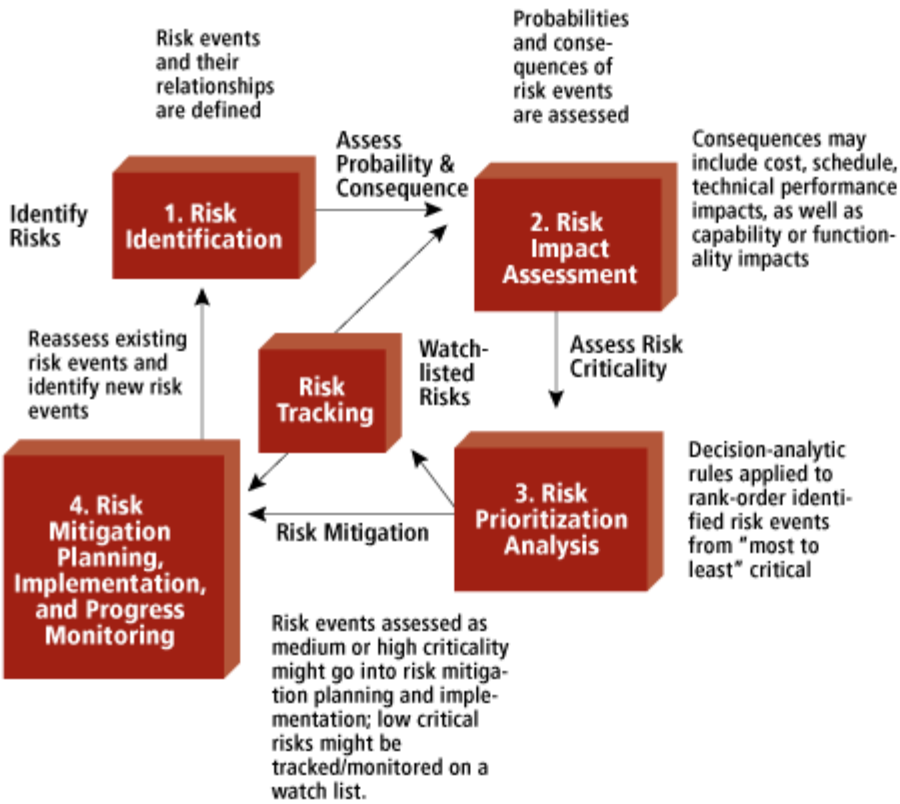


Figure 12 - Risk Assessment Methology

6.1 RISK IDENTIFICATION

The risks of this project include, but are not limited to:

- Short-term rigidity
- Schedule Alignment

- Task Delegation
- Materials Ordering
- Budget
- Testing
- Analysis and documentation
- Long-term reliability
- Initial Project Scope
- Limited Access to Tools
- Limited access to specific parts
- Motor speed control

6.2 RISK ANALYSIS

Table 4 - Risk Analysis

Item	Project/ Phase	Risk Status	Risk	Potential Impact (Cause and Effect)	Risk Response Strategy	Triggers (Indicators that the risk will occur)	Estimated Schedule Impact (Days)	Maximum Exposure ($000)	Estimated Exposure (Contingency) ($000) $32	Risk Category	Risk Sub Category	Action Owner	Start Exposure	End Exposure	Baseline Risk Scoring: Impact: Tech Perf	Baseline: Impact: Schedule	Baseline: Impact: Cost	Baseline: Impact: Safety	Baseline: Probability	Baseline: Risk Ranking	Current Risk Score: Impact: Tech Perf	Current: Impact: Schedule	Current: Impact: Cost	Current: Impact: Safety	Current: Probability	Current: Risk Ranking	$%	
0		Open	Short-term ridity	Does not hold up to forces in the short-term	Build the frame from 2 x 4 materials and use wood glue on all the joints	Model does not remain rigid during testing	1	$35	$0	Performance											4	1	2	3	2	8	0%	0.00
1		Open	Schedule Alignment	Deadlines for project are missed. Project goes over-time and over-budget.	Weekly progress meeting to align the schedule to reflect our current standing	Due dates approach and no work has begun on said assignment	2	$25	$3	Schedule						1			5	5	1	3	1	1	2	6	8%	0.50
2		Open	Task Delegation	Tasks are unevenly delegated and work-loads are skewed due to it.	Use of MS project to identify over-scheduled people and move tasks around to account.	Some people are workiong far more than others	2	$15	$2	Schedule						1			5	5	1	3	1	1	2	6	5%	0.30
3		Open	Materials Ordering	Not able to start the build on time	Plan on what materials are needed and research the lead-times expected	Materials delivery date extend up to or after the project deadline	7	$30	$3	Schedule						2			3	6	1	4	2	1	2	8	10%	0.80
4		Open	Budget	Spending more money then is needed	During the materials identification, include cost breakdown to calculate the projected cost of the project.	The project goes over budget	0	$50	$1	Financial/Regulatory						5			5	25	1	5	5	1	1	5	4%	0.20
6		Open	Testing	The working model does not function as intended if not tested first	During the project build, test the design at certain milestones of the build to verify it functions properly.	The project fails or losses functionality in the long-term	2	$20	$2	Project Development						1			5	5	2	1	2	2	2	4	7%	0.27
5		Open	Analysis and documentation	Not preforming analysis may result in unforeseen issues.	During/after the build, analyze and document the model for defects or errors.	Issues with the build keep arising	1	$20	$1	Project Development								5	5	25	1	3	2	2	1	3	2%	0.05
7		Open	Long-term realiability	The product does not hold up long-term	Build the frame with some metals parts in addition to the wooden frame to allow for long-term lasting.	The frame does not hold up to normal operation	1	$50	$5	Performance											4	1	2	3	2	8	17%	1.33
8		Open	Initial Project Scope	The scope of the project was not outlined properly at the start of the project.	Clarify the intent and scope of the project at the beginning. Retrospect to future projects.	The project fails to meet the requirements	3	$40	$4	Project Development											2	3	2	1	2	6	13%	0.80
9		Open	Limited Access to Tools	May result is delays due to enefficiently	Schedule times with the professors to get access to campus tool shops on a regulary basis.	The build does not get done correctly or on-time	3	$25	$8	Schedule											1	3	2	1	3	9	26%	2.36
10		Open	Limited access to specific parts	Long lead-times for unique parts	Machine specific or unique parts may take additional time to get. Plan these out and order ahead of time.	Proformance of build will decrease if unique parts are unavaiable	5	$15	$2	Schedule											1	3	2	1	2	6	5%	0.30
11		Open	Motor speed control	Single use speed for inexpensive motors may cuase lack of funacionality for different sized parts.	Build in an input govener to control speeds of the motor.	Does not sort or funnel the materials as intended	1	$10	$1	Performance											3	2	1	2	2	6	3%	0.20

6.3 RISK PRIORITIZATION

Given the analysis of the risks, we decided to focus on the following items; materials used to address long-term concerns, ordering parts ahead of time to address the lead times concern, and fine tuning the project scope to address the delays concern. The aforementioned risks, among the rest of the risks, can be found in the photo above.

7 CODES AND STANDARDS

7.1 IDENTIFICATION

With the knowledge that springs would be an integral part to the performance, they were a logical piece of the assembly to compare to current codes and standards. Springs are manufactured to very specific sizes and properties. Values such as K-value, inner and outer diameter, type of steel, wire diameter, length when compressed and max load all dictate when and where they can be used. The compression springs used in this assembly needed to be a certain length and stiffness to produce effective vibration. The following standards indicate recommended range of vibration for springs in different applications.

7.2 JUSTIFICATION

The first code was chosen because the springs would be directly behind how our tray would vibrate. If our springs were too stiff or too loose, the tray wouldn't vibrate enough or vibrate too much, respectively. Taking into account the shape of the spring, naturally, a cylindrical helical compression spring would be our best option. The codes and standards allowed us to further learn about the values that would impact performance. The second code was chosen because knowing the severity of vibration for our motor would be paramount to identifying if our project would fail or succeed. Too little and there'd be little more than a murmur. Too much and the project itself may collapse. The code helped us identify if the vibration would be good or satisfactory in this regard.

7.3 DESIGN CONSTRAINTS

See below.

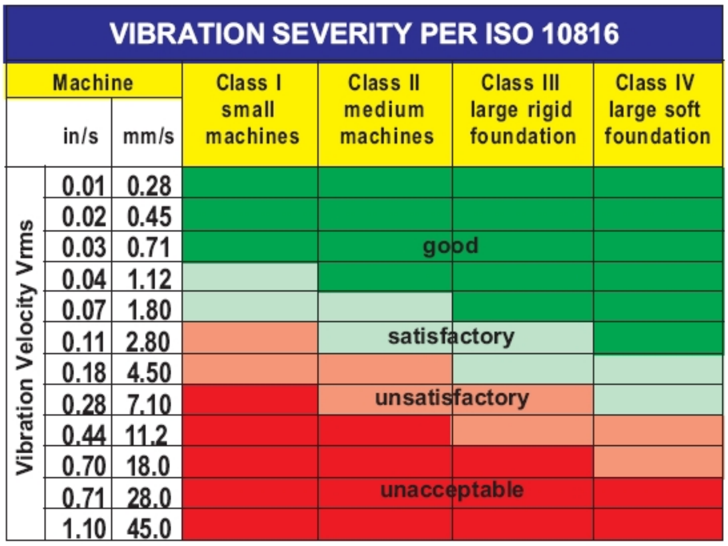
7.3.1 Functional

ISO 22705 - Cold Formed Cylindrical Helical Compression Springs

7.3.2 Safety

ISO 10816 - Vibration Severity Standards

Table 5 - Vibration Severity Standards



7.4 SIGNIFICANCE

Identifying codes and standards before the prototype or engineering work has begun is crucial to the success of the build. Recognizing the standards similar to what is followed in the field can greatly improve the odds of identifying mishaps early into the project. It is for this reason that identifying and following ISO standards is so significant to the success of the project.

8 WORKING PROTOTYPE

8.1 PROTOTYPE PHOTOS

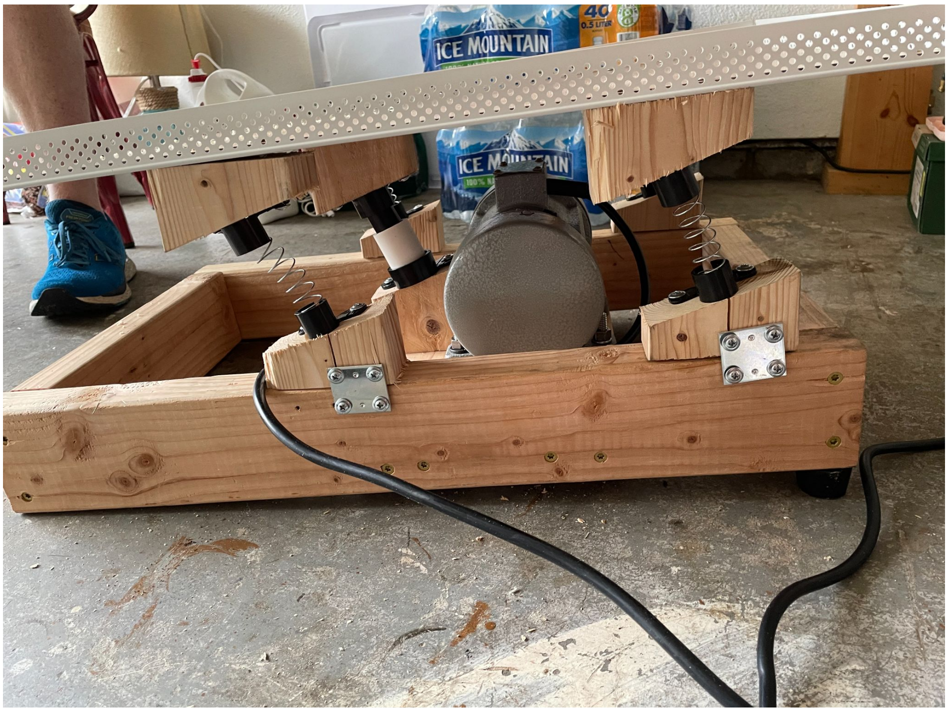


Figure 13 - Prototype Photo 1

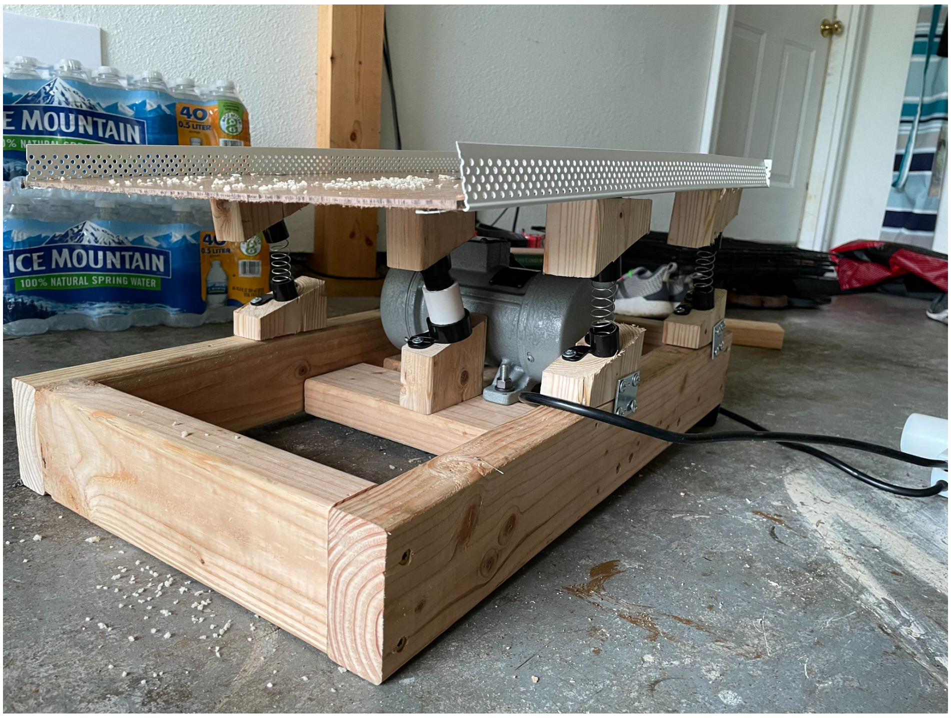


Figure 14 - Prototype Photo 2

8.2 WORKING PROTOTYPE VIDEO

[Vibratory Parts Feeder]

8.3 PROTOTYPE COMPONENTS

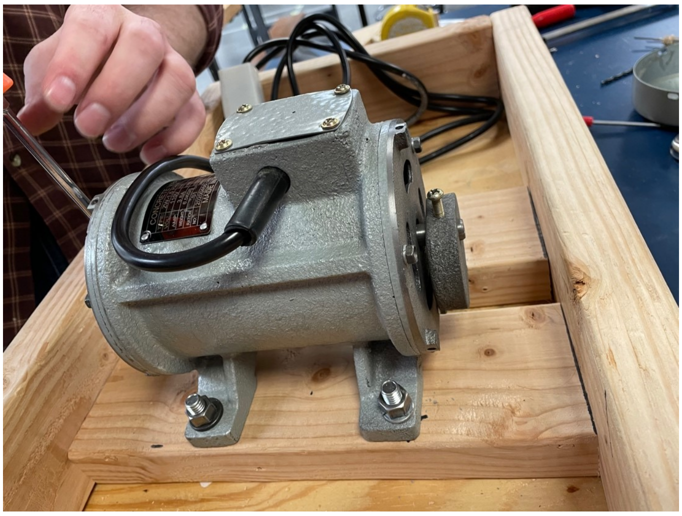


Figure 15 - Motor

1. Motor – Our motor was a 110V, 3.8A, 6.5kg, 3600 RPM, with two 0.6lb offset weights located on either end of the motor. Because this provided too powerful of a vibration, it was modified so that the weights were cut in half in order to provide a more stable vibration. The motor was bolted into our frame.

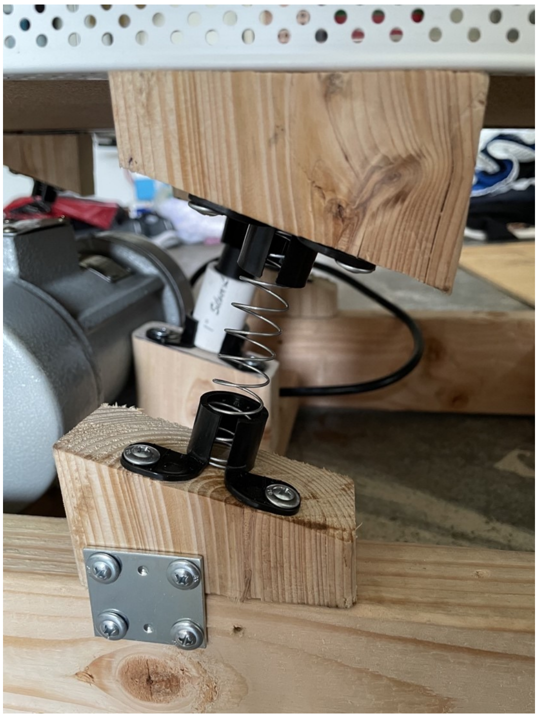


Figure 16 - Spring Supports

2. Spring Supports – Our spring supports were created by taking angled pieces of wood and screwing in a plastic pipe support on both pieces. A metal bracket was then

screwed into both the angled piece of wood and the frame to give some rigidity to the support. A spring was then placed within the supports to give it additional bounce. This was done 4 times (2 on each side of the frame) to give proper support to the tray.

Figure 17 - Tube Support

3. Tube Support – Tube support that was placed in the middle of our design. This was done in a similar fashion by taking 2 angled pieces of wood and screwing in the plastic pipe support. 2 different pieces of pipe (one goes inside the other) were then placed with the plastic to act as a sort of pseudo-pneumatic system to connect our frame to the tray.

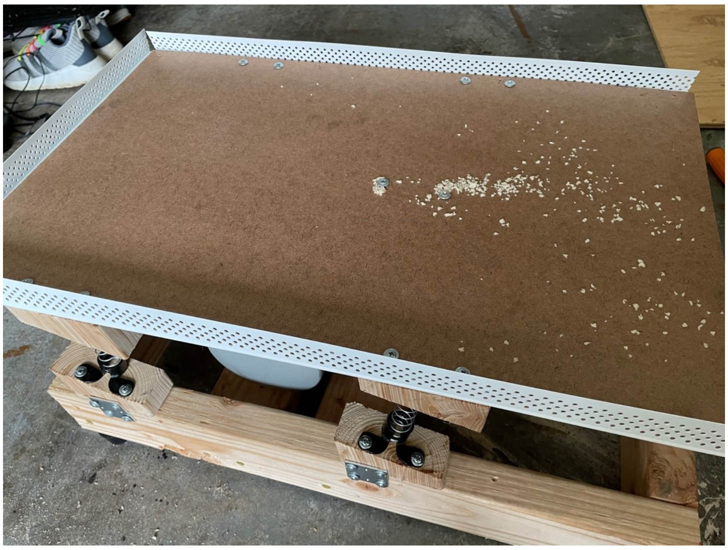


Figure 18 - Tray

4. Tray – Tray made from plywood with the dimensions of 23.75 in by 15 in. The border was made using plastic corners. This was then connected to the 4 spring supports on the side with the middle tube support as well.

9 DESIGN DOCUMENTATION

9.1 FINAL DRAWINGS AND DOCUMENTATION

9.1.1 Engineering Drawings

See Appendix C for the individual CAD models.

9.1.2 Sourcing instructions

Given the bill of materials below (appendix B), sourcing the materials required for this project should be relatively easy. The majority of the components are from McMaster Carr and a home improvement store (Lowes or Home Depot). The motor was purchased on eBay, but another online seller would also suffice.

Table 6 - Purpose Table

No	Item Description	Purpose
1	US Stock 110V, 100W Motor	The motor is intended to vibrate the trough and will be mounted to the base
2	Tempered Steel Compression Spring	These springs transpose the force/vibrations of the motor to the trough.
3	Plywood, 11/32" x 4' x 8' sheet	The plywood will be used not only for the bottom of the base but also the bottom of the trough
4	2in x 4in x 8ft. Kiln-Dired Whitewood	This wood is used for the base assembly
5	Vibration-Damping Mount w/ Unthreaded Hole	These will be used as the feet for the base unit
6	#8 x 1-1/2 in. R4 Multi-Purpose Star Drive Flat Head Screw	These screws will be used to fasten the base frame together

7	Titebond III 8 oz. Ultimate Wood Glue	The wood glue is used to secure the base and trough
8	SharkBite Plastic Suspension Clamps	These clamps are used to attach the base from to the trough

9.2 FINAL PRESENTATION

See link in section 8.2

7 APPENDIX A - PARTS LIST

See section 4.2 for parts list.

8 APPENDIX B - BILL OF MATERIALS

Table 7 - Bill of Materials

No	Item Description	Vendor	Part Number	Unit	Unit Cost	Qty	Material	Total
1	US Stock 110V, 100W Motor	eBay	393426794827	Each	$69.99	1	N/A	$69.99
2	Tempered Steel Compression Spring	McMaster Carr	96485K135	Each	$11.75	4	Carbon steel	$47.00
3	Plywood, 11/32" x 4' x 8' sheet	Home Depot	112590	Each	$33.33	1	Pine Wood	$33.33
4	2in x 4in x 8ft. Kiln-Dired Whitewood	Home depot	418545	Each	$10.42	1	Whitewood	$10.42
5	Vibration-Damping Mount w/ Unthreaded Hole	McMaster Carr	60525K25	Each	$4.08	4	PVC Plastic	$16.32
6	#8 x 1-1/2 in. R4 Multi-Purpose Star Drive Flat Head Screw	Home Depot	96085	Box	$9.98	1	Steel	$9.98
7	Titebond III 8 oz. Ultimate Wood Glue	Home Depot	202960636	Each	$5.97	1	Glue	$5.97
8	SharkBite Plastic Suspension Clamps	Lowes	818224	Each	$0.55	1	Plastic	$4.40

9 APPENDIX C – COMPLETE LIST OF ENGINEERING DRAWINGS

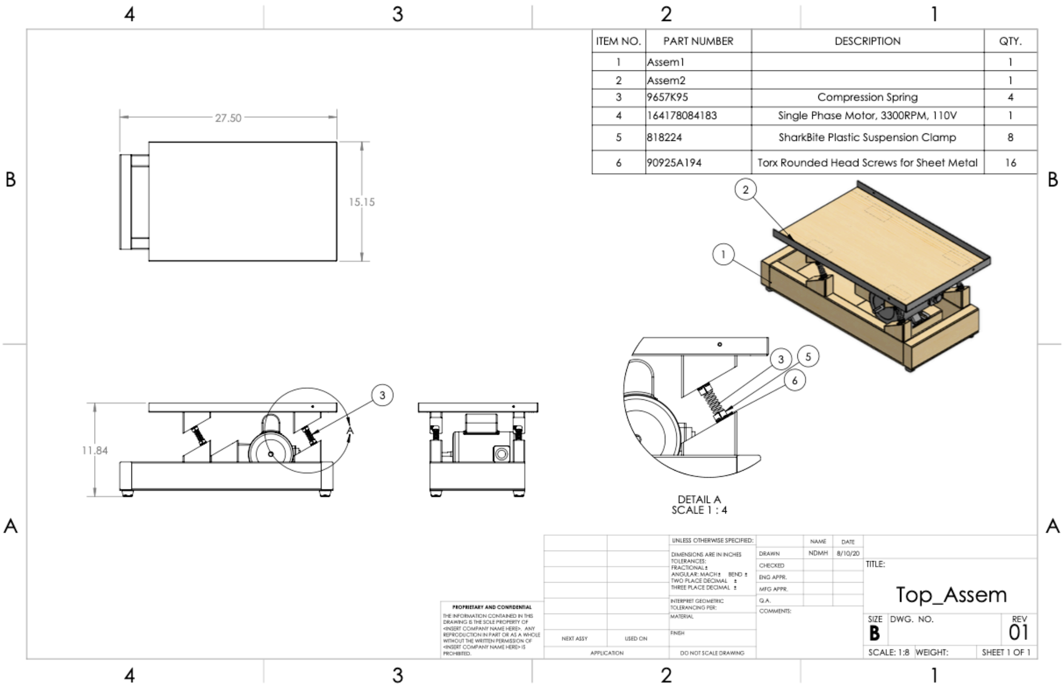


Figure 19 - Top Level Assembly

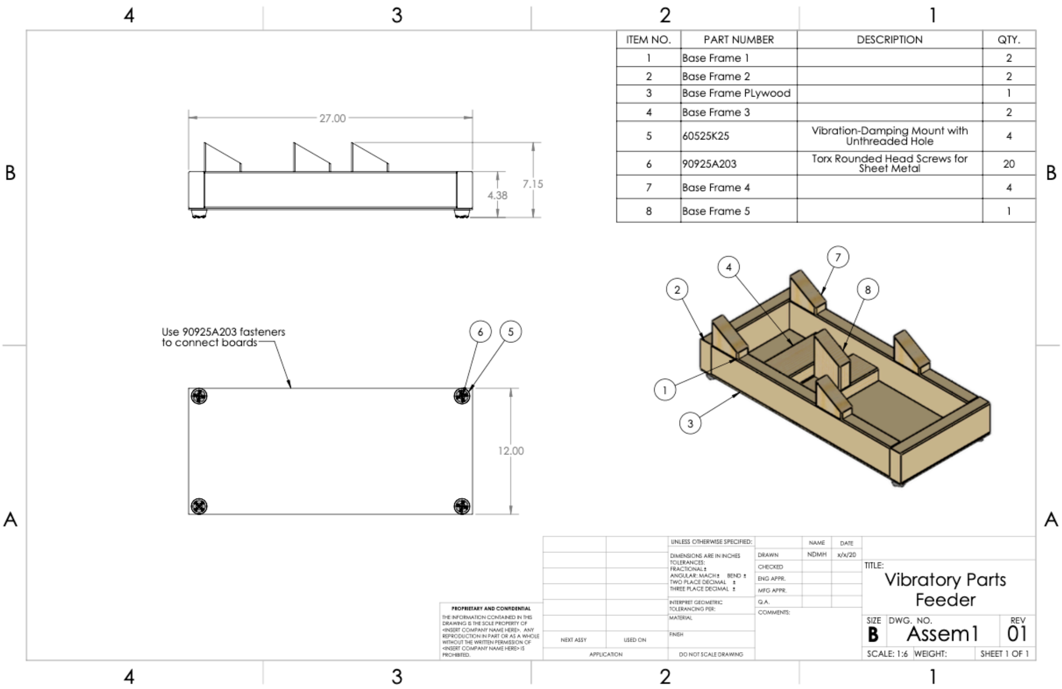


Figure 20 - Sub-Assembly 1

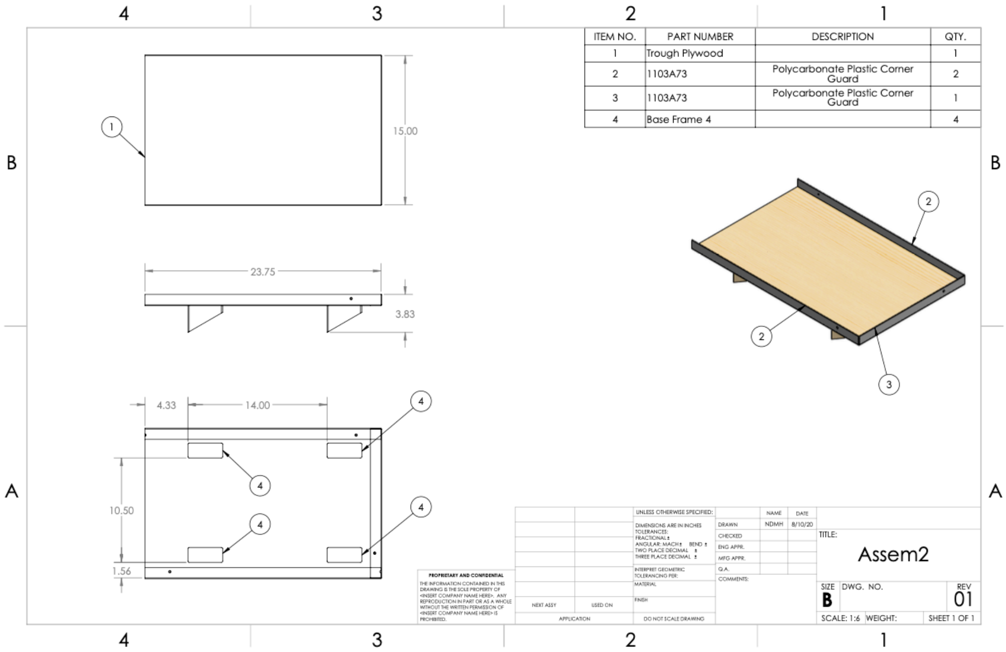


Figure 21 - Sub-Assembly 2

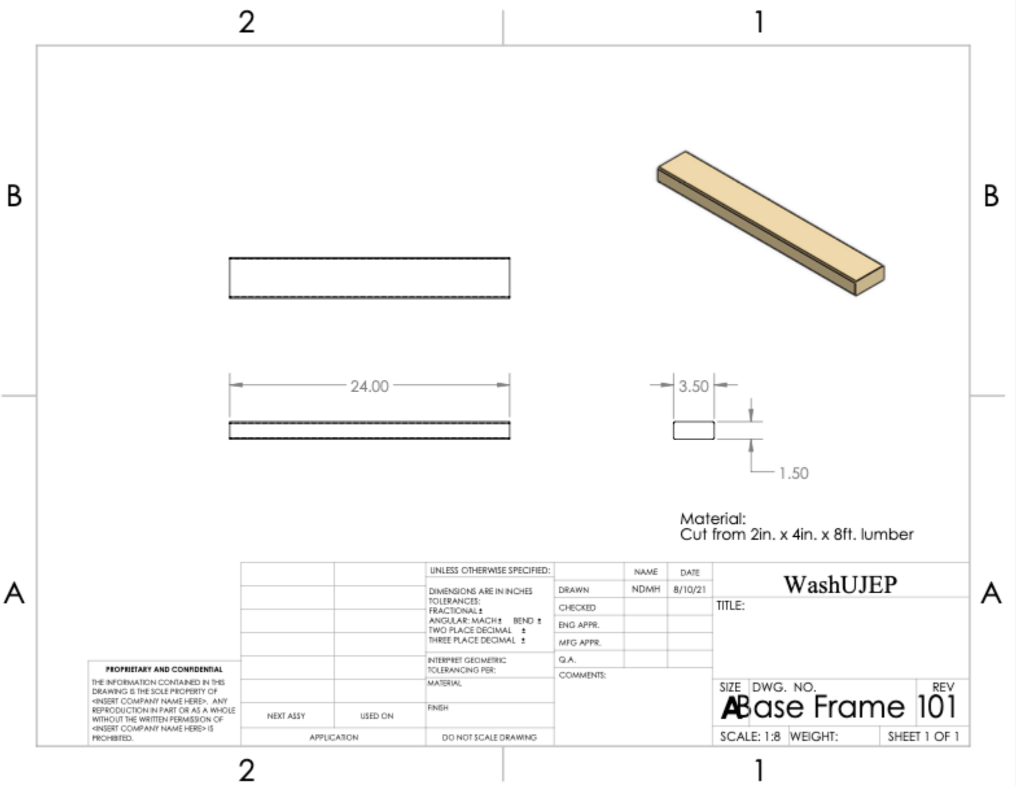


Figure 22 - Part Drawing 1

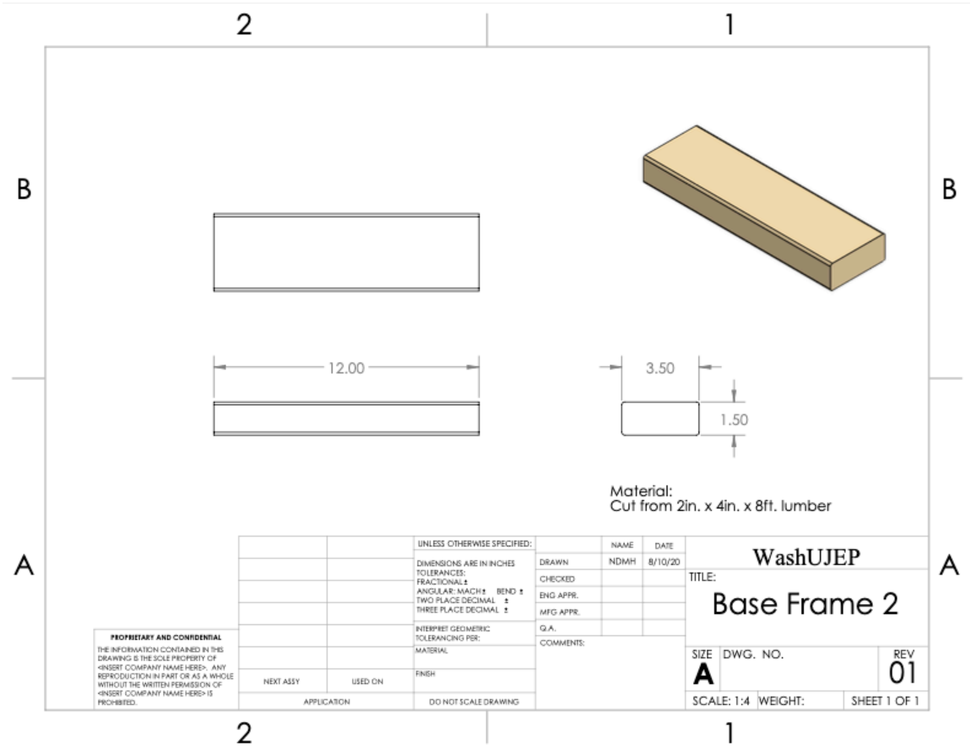


Figure 23 - Part Drawing 2

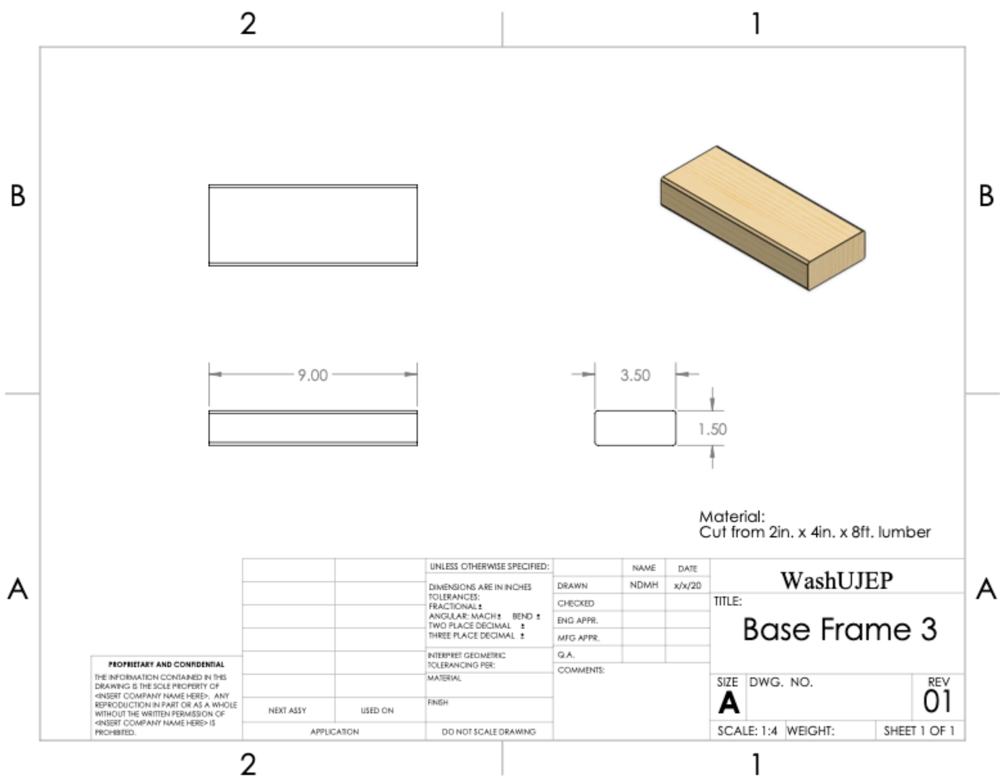


Figure 24 - Part Drawing 2

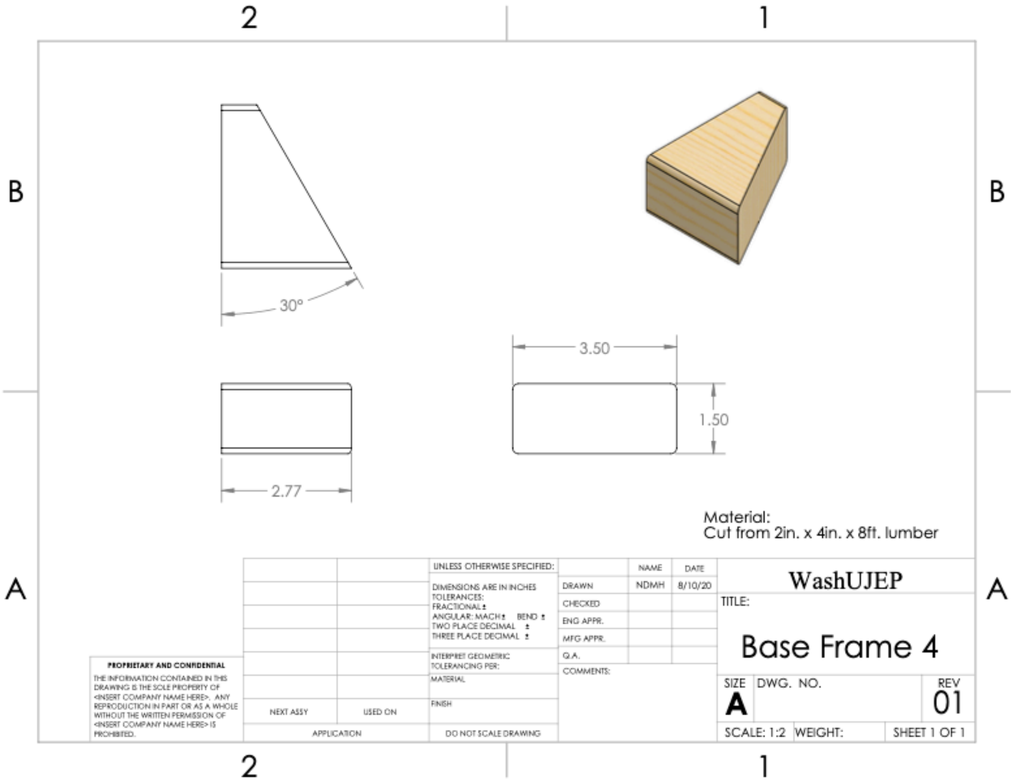


Figure 25 - Part Drawing 3

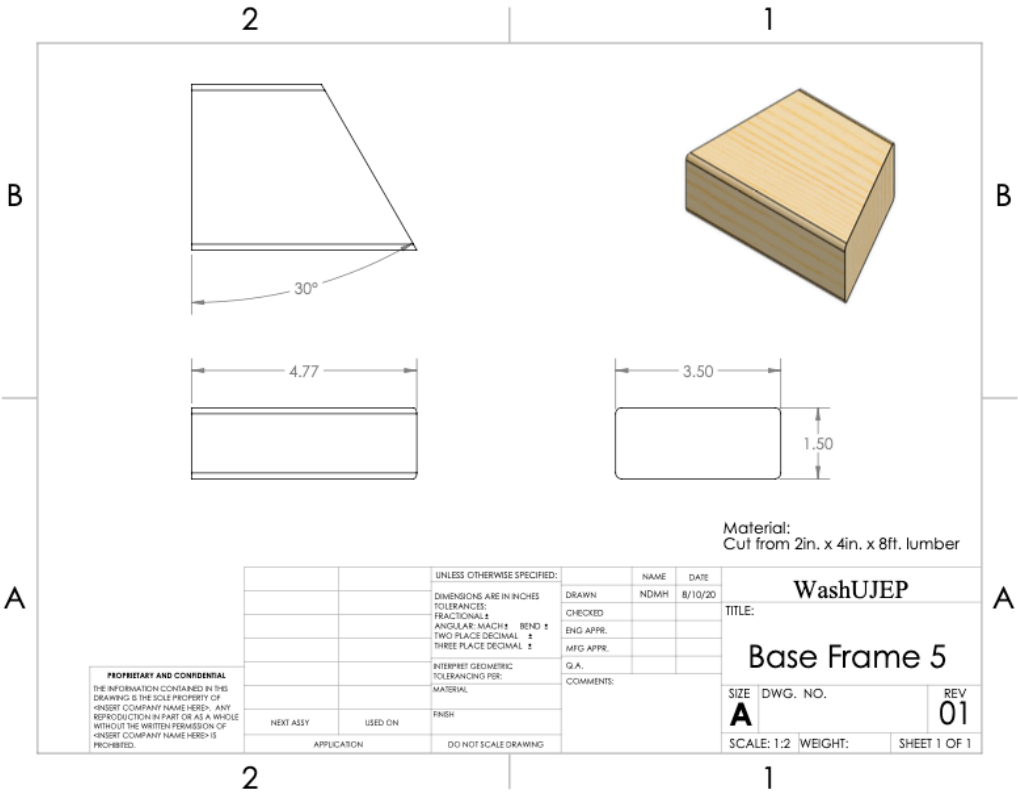


Figure 26 - Part Drawing 4

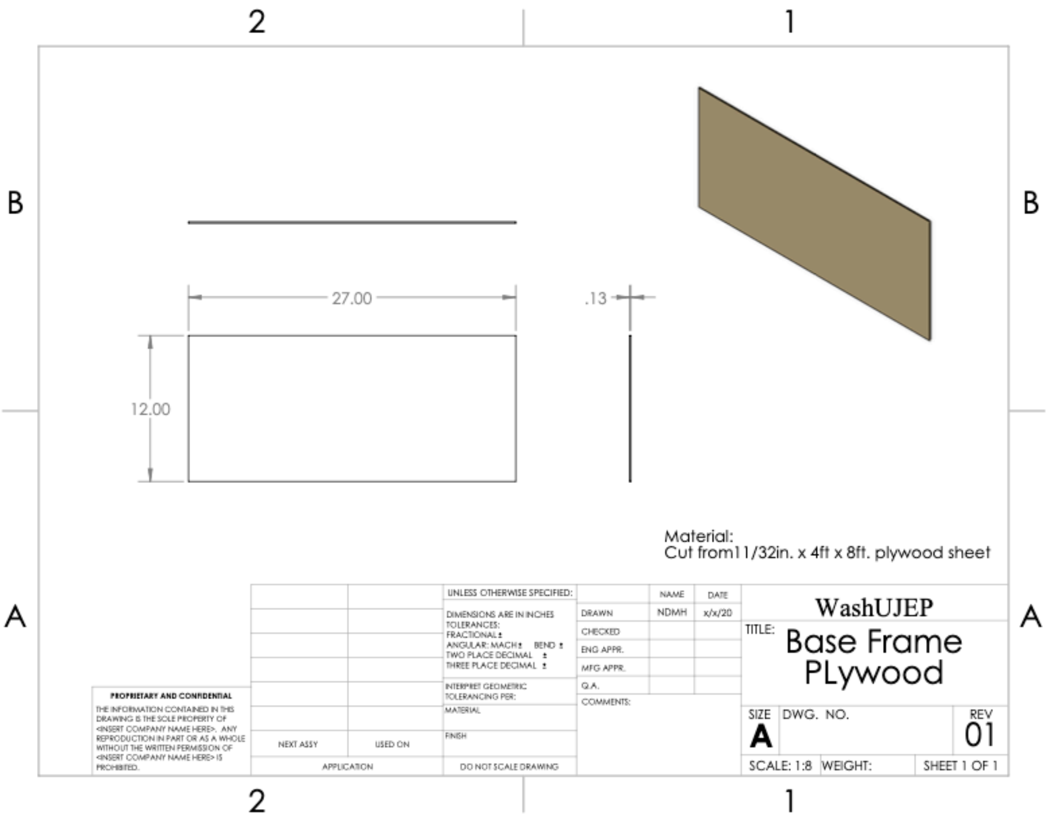


Figure 27 - Part Drawing 5

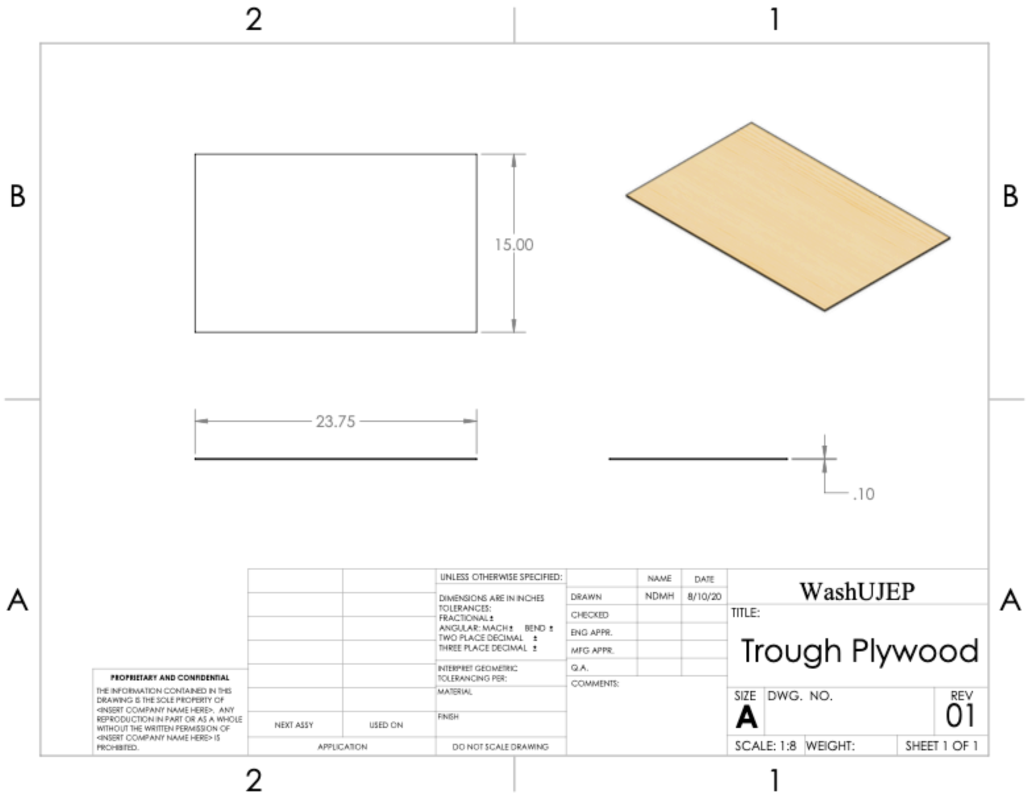


Figure 28 - Part Drawing 6